Combining High Dynamic Range Photography and High Range Resolution RADAR for Pre-discharge Threat Cues

Nikola Subotic
Nikola.Subotic@mtu.edu

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Project Objective:

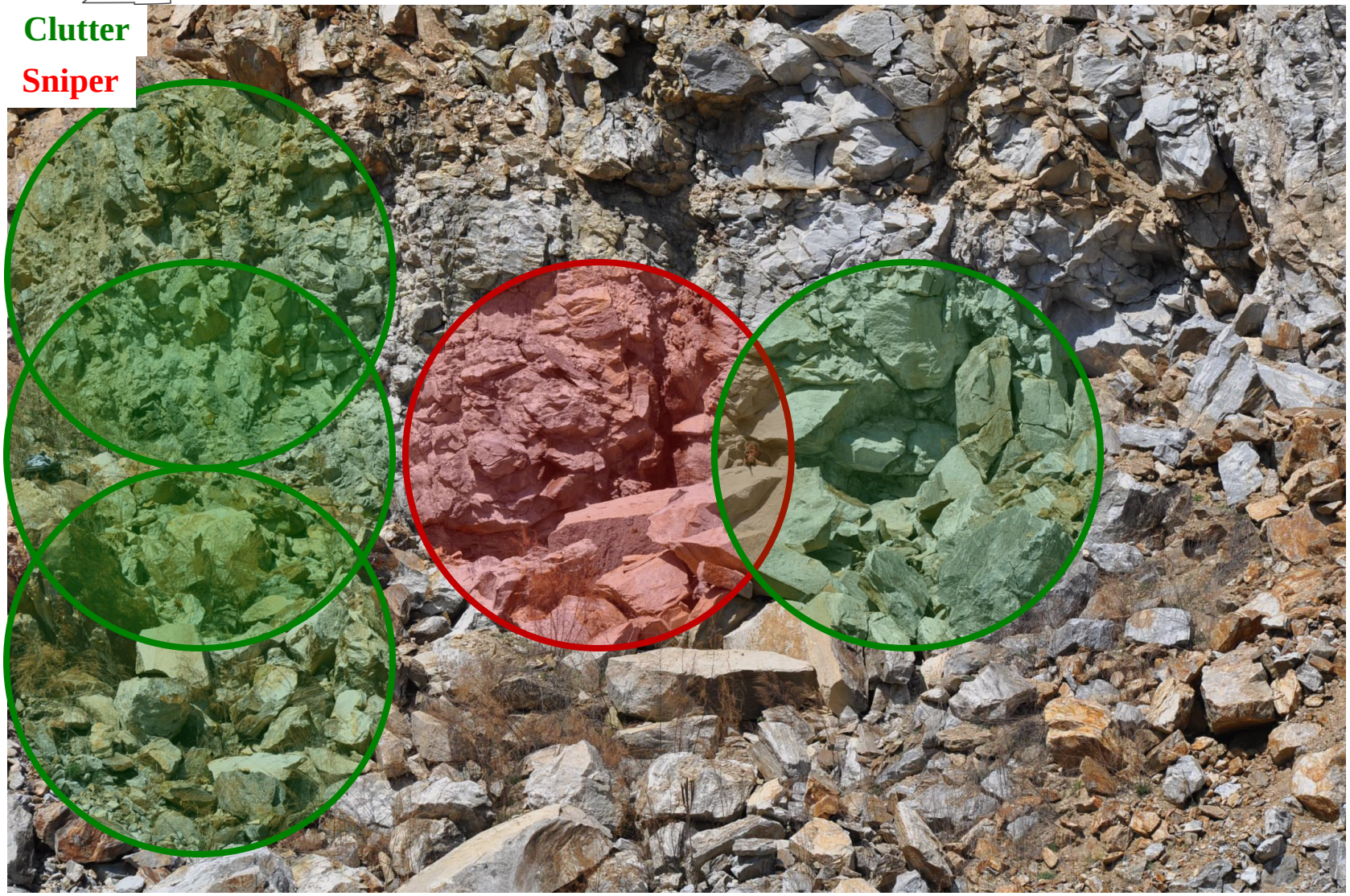
- The objective of this project is to develop a joint high dynamic range photography and high range resolution RADAR system on mobile platforms to provide pre-discharge threat warning in urban and mountain environments.

Approach:

- Expand upon the sensor and processing concepts of MTRI Counter RPG and Counter Sniper programs.
  - The expansion of the system will be in the areas of
    - rural, mountainous terrain and threats
    - incorporating cued high dynamic range imagery to the warfighter.
    - Clutter rejection and target detection algorithm variants will be developed
    - develop a parallel aperture high dynamic range optical system along with its attendant signal processing
      - provide confirmatory images of the threat as cued by the RADAR.
      - high dynamic range optical system will be cued by the RADAR in operation
  - Deploy our instrumentation RADAR and optical system at mountainous sites for empirical collections to verify performance
  - Provide a near real-time demonstration of the system.

Optical Difficulty: Find the Shooter

Radar Locates Potential Threat



*** Chart is Animated in Slide Show Mode**

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Shooter is Located

Impacts of Mountain/Rural Clutter

- Moving from “Sniper in Building” to “Sniper in Mountainous Terrain” – significant differences

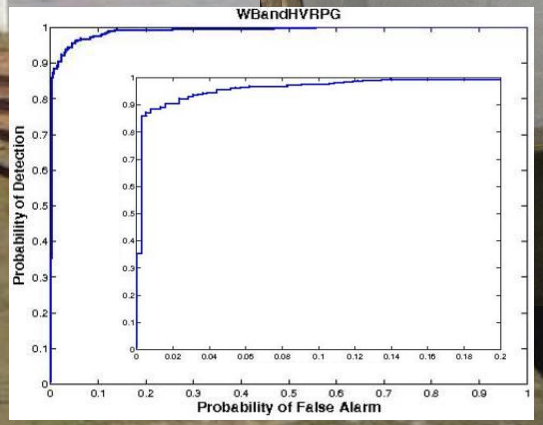
Urban	Mountainous
Bright and more localized discretes	Diffuse and distributed scatters
Fast changes in spatial clutter	Slow to moderate changes in spatial clutter
Predominance of flat surfaces (walls/furniture)	Distribution of rocks and vegetation
More control of incident angles	Wide variety of incident angles
Clutter = combination of several discretes	Clutter = variety of distribution of scatterers (moderate to heavy-tailed)
Polarimetric – known distinct differences between targets/clutter	Polarimetric – expect differences but less distinct between targets/clutter
Weapon variety – mod variability	Weapon variety – more variable
Focused Scan Area (windows, roofs, edges of buildings)	Larger Scan Area (more possible locations)

Ft. Pickett Collection Campaign

March, April 2008

W and Ka bands collected

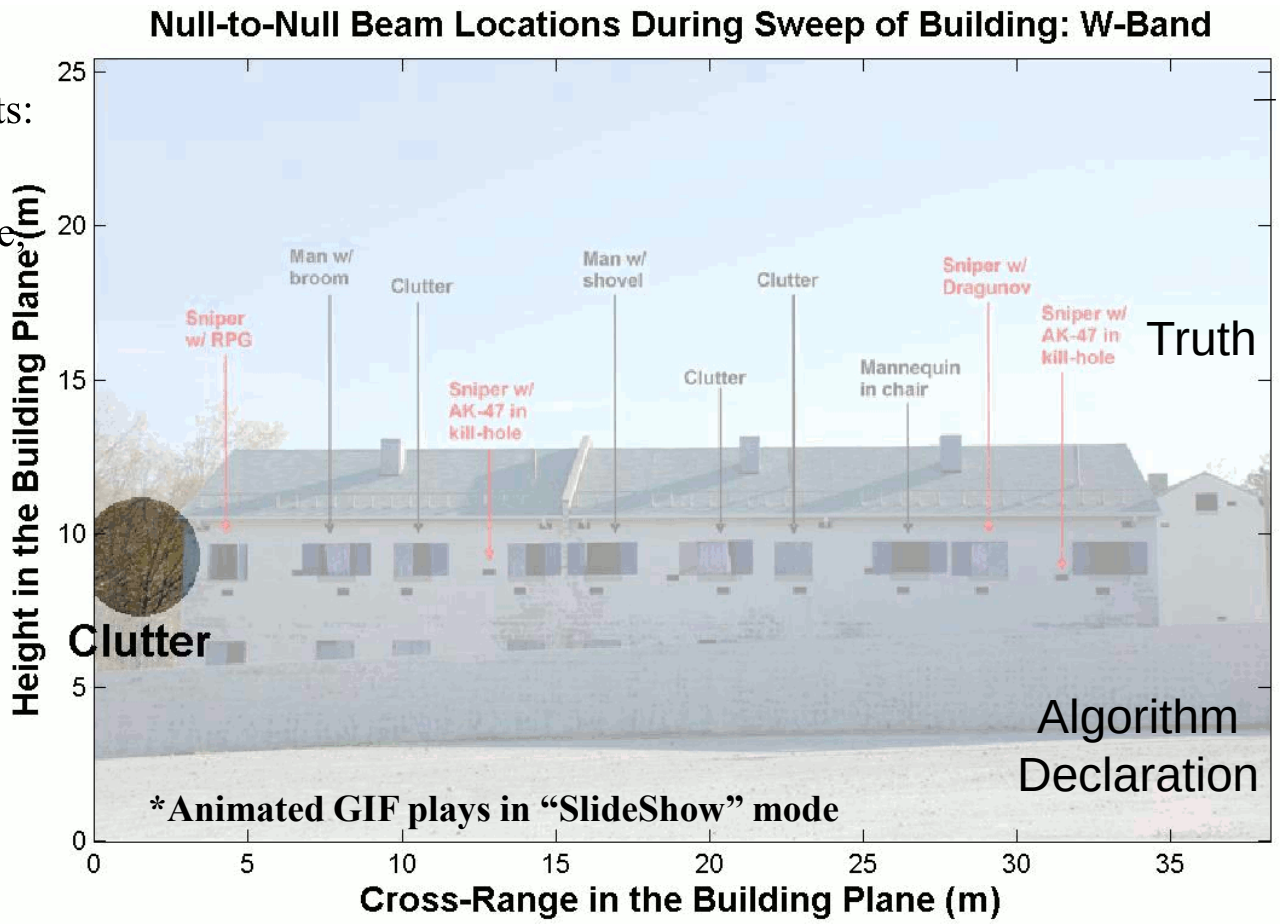
Ave Pd=.95 at Pfa=.05



Blind Test Results Show Detectable Signatures in Clutter

- Radar scanned across building with blind target deployment
  - Complex clutter in room including holes in walls, steel furniture and large wooden ladder
  - Deployed behind fully open, half open windows and "kill hole"
- Syst

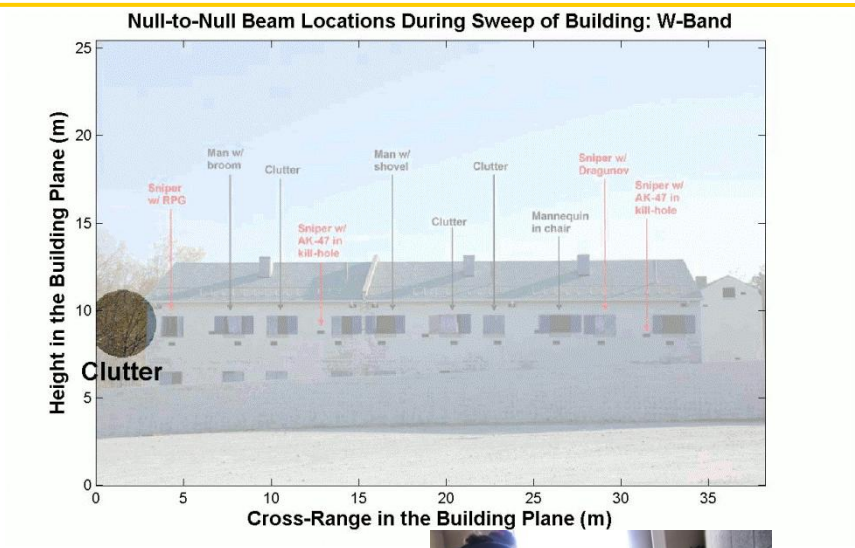
- Real Threats: AK-47, Dragonov Sniper Rifle, RPG-7



False Threats:

- Broom
- Shovel
- Ladder

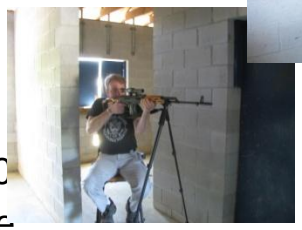
RADAR Demonstration Structure



- Scan set #1
  - False alarm testing
    - Scan #1: building with confuser targets
      - Empty rooms, people, people with implements
        - » Positioning of people determined on site with government
    - Scan #2: completely empty building, shutters open
    - Scan #3: empty building with shutters closed
- Inspection of processing results
- Scan set #2
  - Detection testing
    - 3 Scans
    - 4 Weapons
      - RPG-7, Dragunov, AK-47, AR-10
    - Positioning of target determined on site with government
    - Confusers added as resources permit








Demo April 2010 Detection Results – tp9042

Scenario

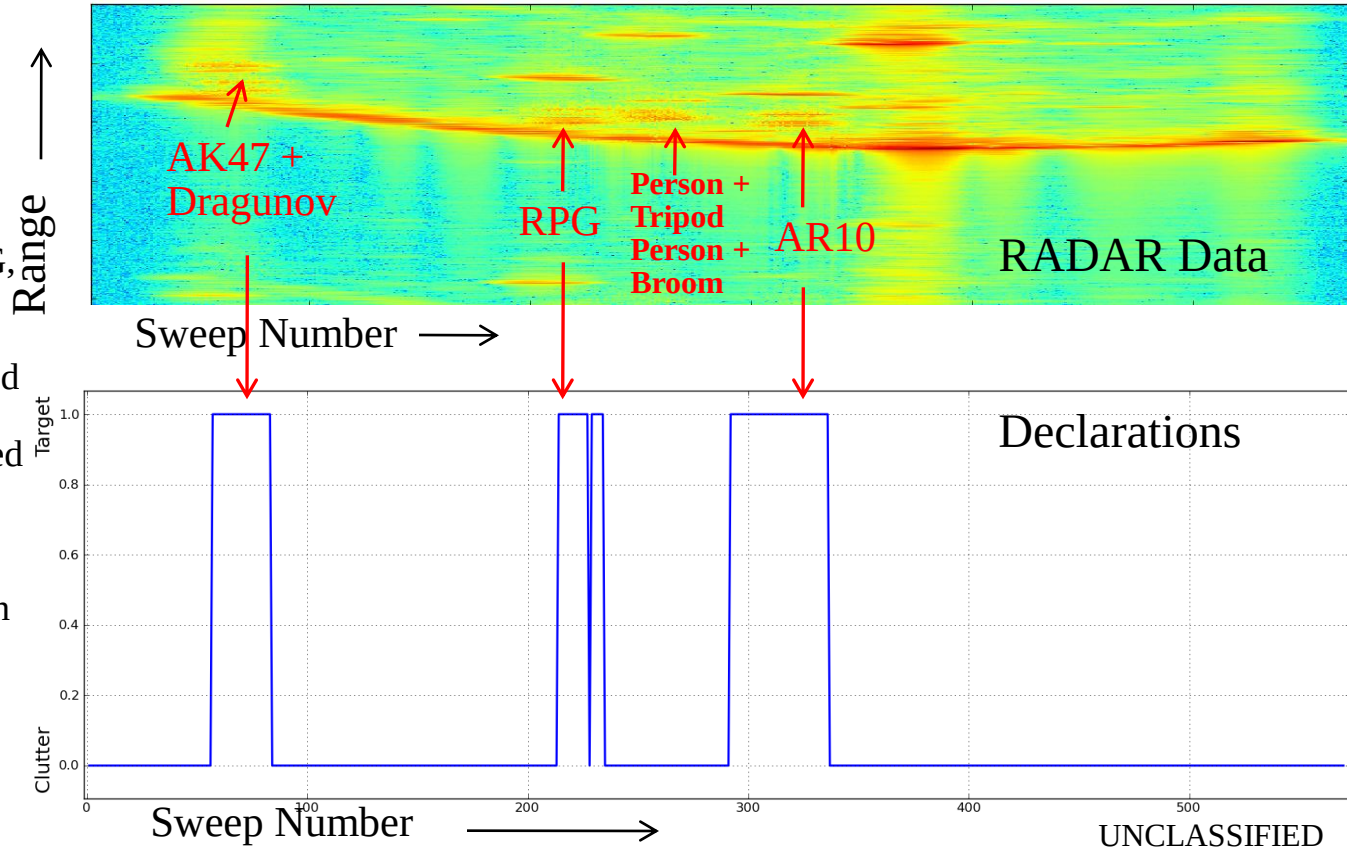
Munitions
- Dragunov
- AK47
- RPG
- AR10

Confusers
- Person with Tripod
- Person with Broom

Results
- Dragunov, AK47, RPG, and AR10 detected as weapons
- Person+Tripod declared as clutter
- Person+Broom declared as clutter

Notes
- AK47 and Dragunov in same room

tp9042



Summary: Algorithm Declarations

	Window 1	Window 2	Window 3	Window 4	Window 5	Window 6	Window 7	Window 8	Window 9	Window 10
Clutter Test, Windows Open										
Clutter Test, Windows Open	Person		Person		Person				Person	Person
Clutter Test, Windows Closed										
Detect Test 1		Dragunov			RPG	Person + Tripod	AK47			AR10
Detect Test 2		RPG			Person + Tripod	AK47	AR10			Dragunov
Detect Test 3	AK47 + Dragunov			RPG	Person+ Tripod Person+ Broom	AR10				

Detection

Missed Detection/ Outside Search Area

False Alarm

Confuser

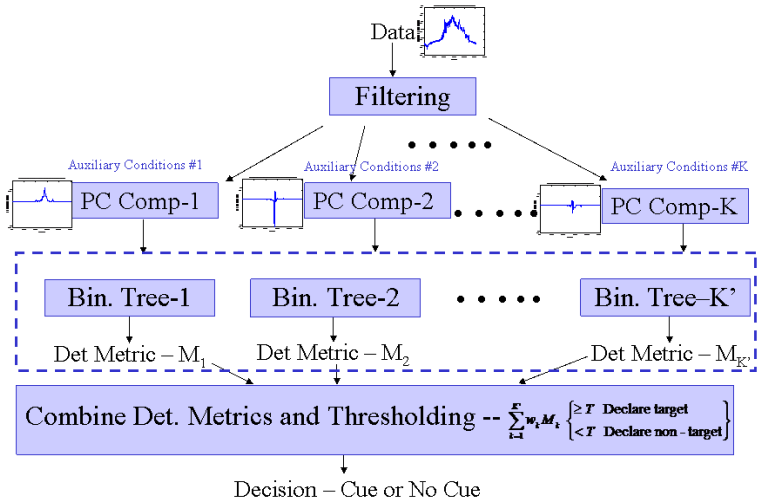
Correct Declaration

Incorrect Declaration

- All weapons within search range of system were detected
- No false alarms
- Automated algorithm used 4 minutes for declarations (non-real time code)

Nonparametric Boosting Classification: Discrimination of Output Cues

- Nonparametric boosting-based rule ensembles
  - Flexible to new operating conditions
  - Doesn't assume Gaussianity
  - Needs relatively moderate amounts training data
  - Robust to over fitting
  - Computationally efficient
  - Approximately optimal (Bayesian Neyman-Pearson Detector)

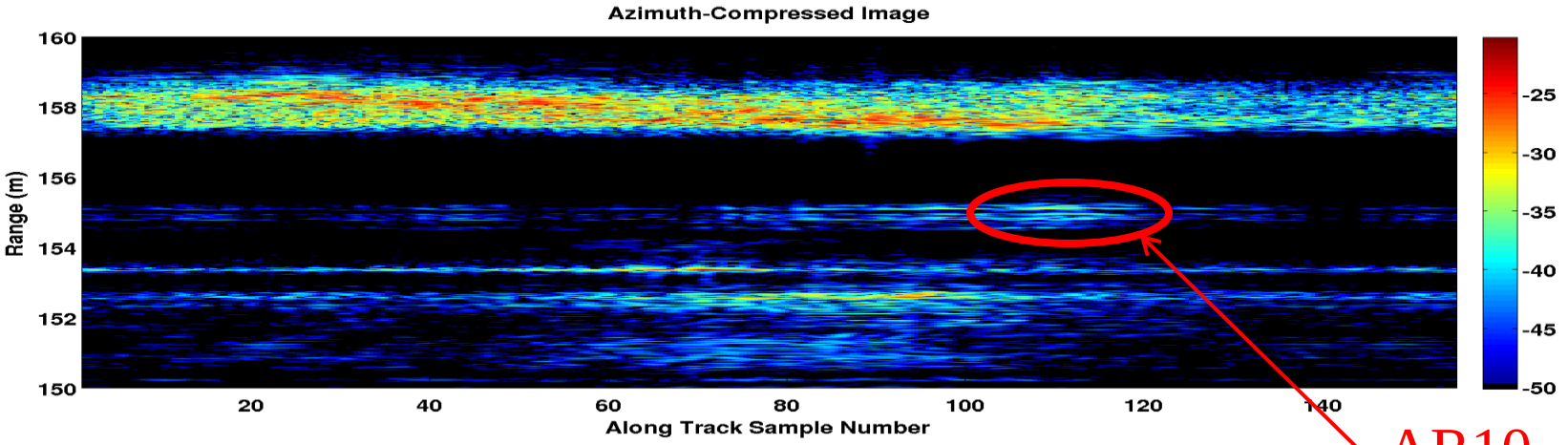


Mountainous Surrogate: Quarry at Ft. Pickett, VA

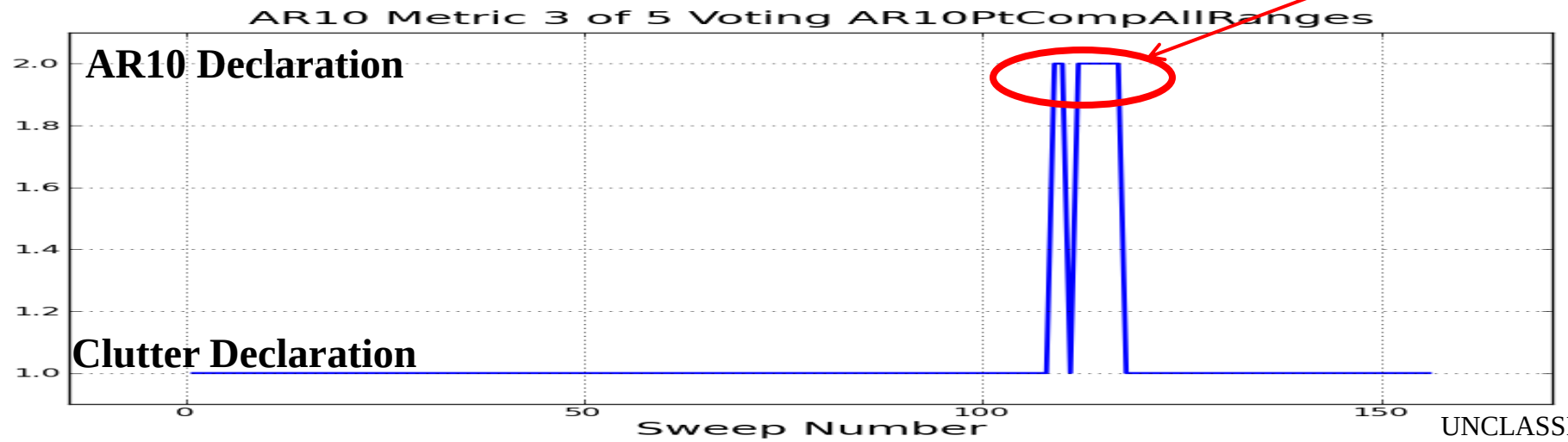
Mountainous Surrogate: Ft. Pickett, VA

Algorithm Declaration After SAR Processing

- Algorithm searched for target over all ranges
- Azimuth compression eliminates false alarm (clutter is localized in azimuth)

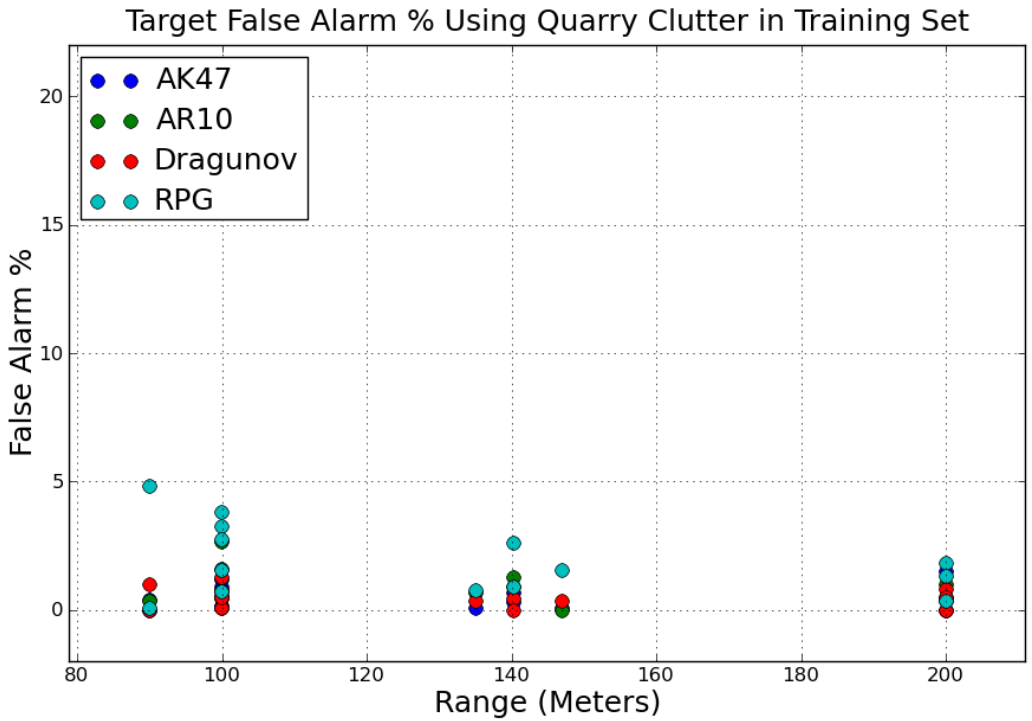


AR10



Quarry Clutter Scans Processed Using Training Sets

- Training sets created from urban target and quarry clutter
  - Training sets are HV, so testing sets are also HV
- Test data was quarry clutter scans



- Expectation that false alarms would decrease with better clutter match was verified

High Dynamic Range Photography

Combination of 4 moderately exposed images

+2 stops

+1 stop

Vs.

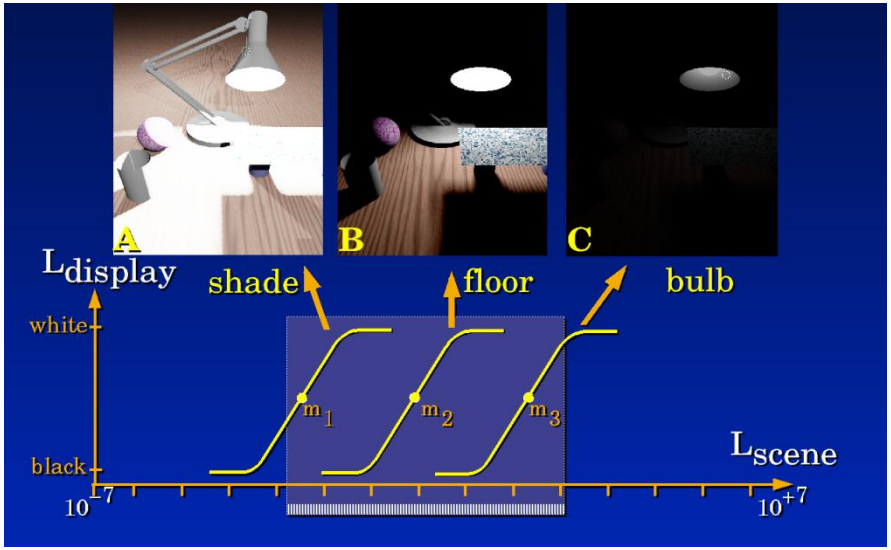
Camera metered as ‘normal’ exposure

-1 stop

Significantly overexposed image (no context)

High Dynamic Range Photography

- Linear Combination of over/under exposed images to increase dynamic range
  - Maximum likelihood
- Tone mapping optimally maps high dynamic range data onto display
  - Local operator using the zone method (local dodging and burning)



$$L_d(x,y) = \frac{L(x,y)}{1+V(x,y;s)}$$

$V(x,y,s)$ - local average over scale s

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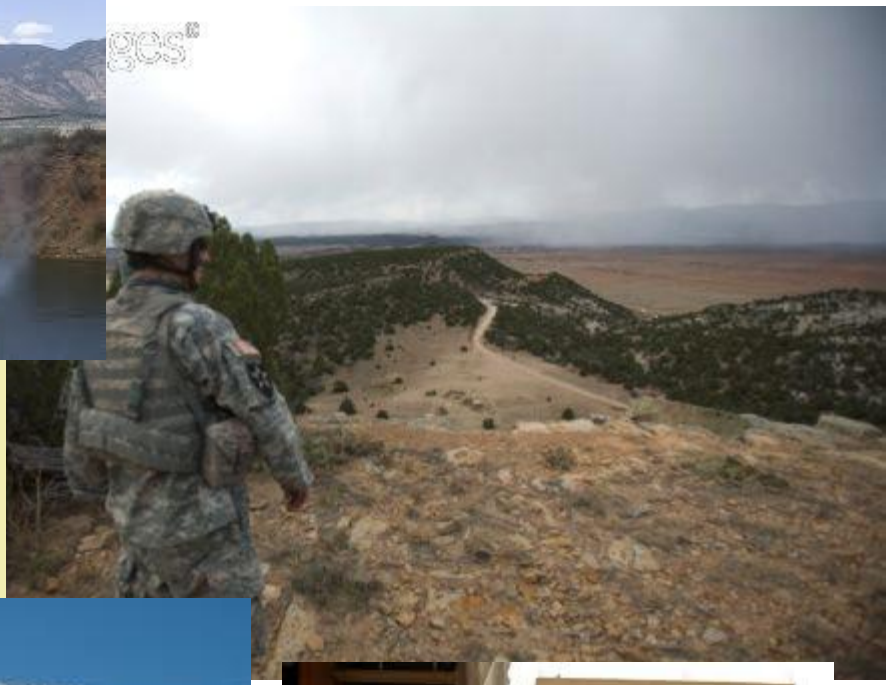
HDR System

Local Mapping Example

Fattal (2002) – Localized gradient based method

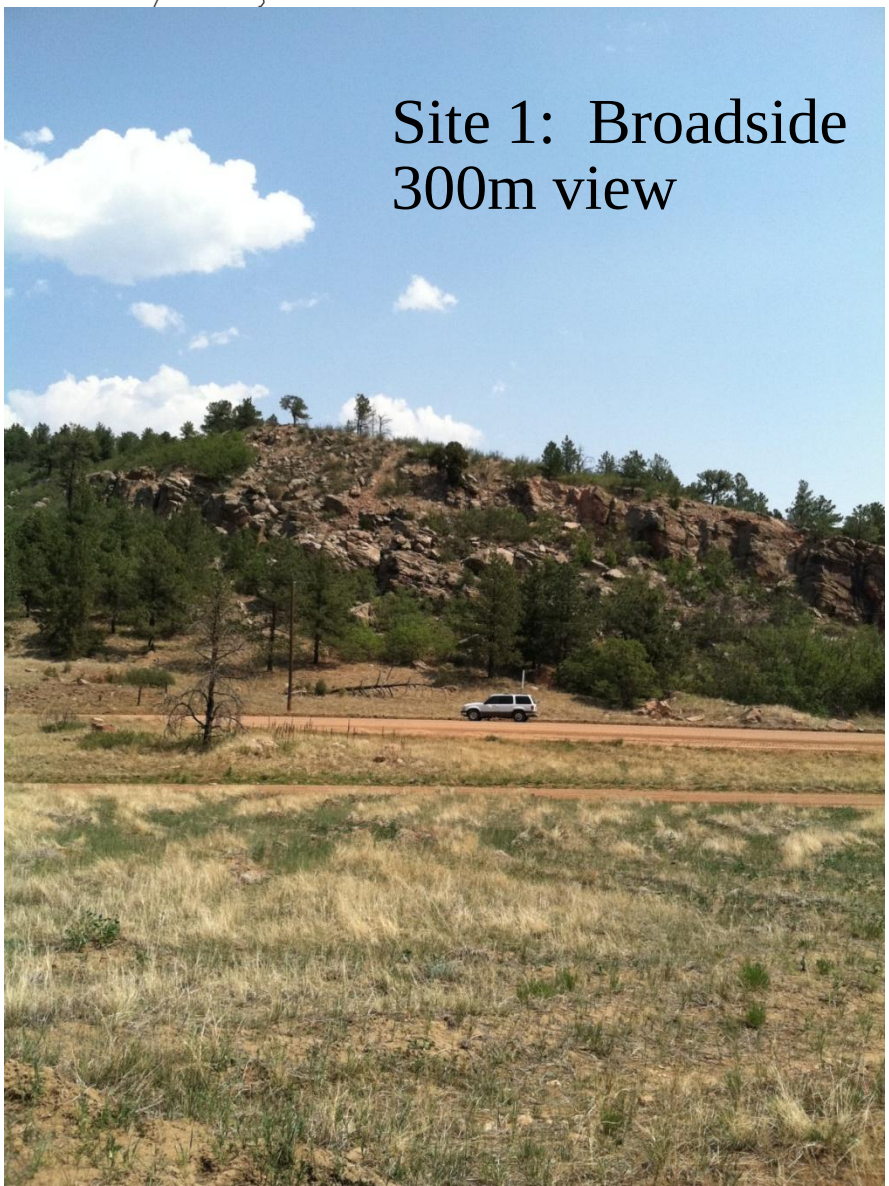
[1 alpha, .8 beta, 1 saturation, no noise reduction]

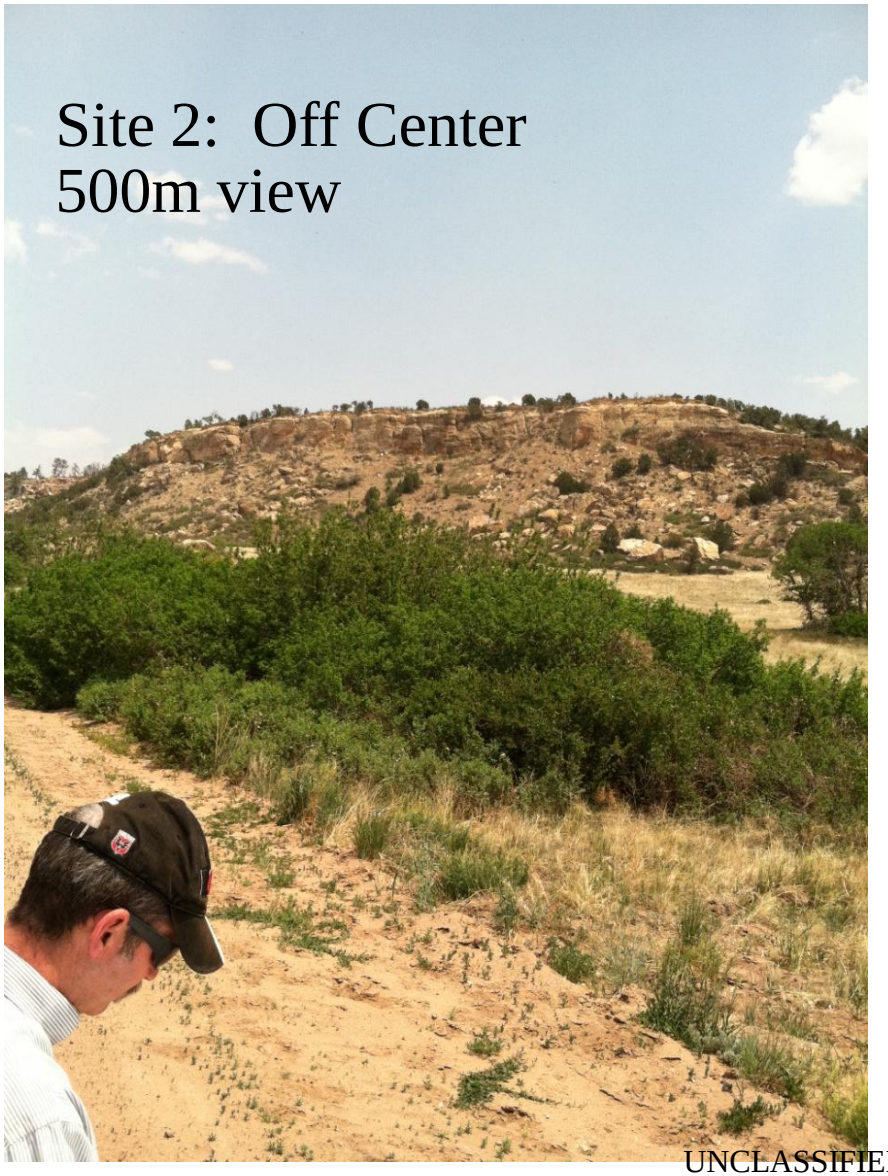
Mountainous Site: Ft. Carson, CO



Fort Carson
and
Evans U.S. Army Hospital

Ft. Carson Site 1





Summary

- Initial results from Ft. Pickett are very promising
  - With minimal training on new data, detection/FA results are quite good
    - Pd=1, Pfa<5%
- Including EO imagery provides actionable imagery to commander
  - RF provides cues
  - HDR alleviates shadowing while maintaining context
- Ft. Carson campaign to commence in early August
  - Much larger data set
  - True mountainous terrain
  - Using both EO and Radar in the collection